THE APPLICATION OF AEA TECHNOLOGY MICROMAP CAPABILITY TO DETECT AND QUANTIFY SURFACE BREAKING AND SUB-SURFACE DEFECTS

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ABSTRACT

AEA Technology's MicroMap was developed as a non-intrusive ultrasonic inspection technique to generate colour-coded corrosion maps of the back wall of vessels and piping in the petro-chemical and nuclear industry. The method relies on a closed circuit video camera tracking a light source that is attached to the ultrasonic probe. The combination of thickness measurement and X-Y co-ordinates allows for the colour-coded maps to be produced and kept for monitoring purposes. However, this technology was limited to obtaining thickness measurement from the back wall.

Applying visual, dye-penetrant and magnetic particle methods can generally identify flaws that occur at the scanning surface. These methods merely indicate the presence of flaws and do not allow quantification or sizing of the defects. The methods also do not allow accurate mapping of the defects for monitoring purposes. A typical example would be the occurrence of stress corrosion cracking (SCC) on an austenitic pipeline. Dye-penetrant application to the surface would probably indicate the presence of cracks, as long as the cracks are surface breaking, and manual pulse-echo inspection will indicate the volumetric extent of the cracks. However, none of these methods can reliably present a record of the extent of the cracking.

The Easy Stress Corrosion Cracking Detection method (ESCOD) allows for the reliable detection and accurate quantification of surface breaking and sub-surface cracking at the scan surface. ESCOD uses the MicroMap technology, which has been configured to accommodate a shearwave probe.

This new principle has also been proven to accurately measure depths of pitting and corrosion from the scan surface.

INTRODUCTION

Surface breaking stress corrosion cracking is generally identified by the use of dye penetrant methods and magnetic particle inspection for the detection of sub-surface indications in ferritic materials. In detecting this type of cracking the volumetric extent of the defects generally requires metallurgical analysis. Conventional ultrasonic inspection methods are able to determine depths of the cracking with the disadvantage that hardcopy evidence of the depth and extent can not be recorded for monitoring purposes.

Fitness-for-service assessments cannot be carried out on sections of pipes or vessels with the results obtained from conventional inspection approaches, especially magnetic particle and penetrant inspections. On this basis remaining life assessment can not be carried out on plant equipment containing defects of unknown quantity. In some cases unnecessary replacement of components occur, more often than not being an expensive option. ESCOD can be used for assessments due to it’s reliable detection, sizing and monitoring capability as well as the hardcopy evidence that can be presented to the Engineer.

This paper presents the results of ultrasonic testing trials on test pieces and plant piping to determine the effectiveness of the Easy Stress Corrosion Cracking Detection method (ESCOD), this being to detect both SCC and pitting corrosion at the outer surface of the pipework and to provide a flaw depth for remaining wall thickness estimates.

THE ESCOD PRINCIPLE

AEA Technology MicroMap System

The AEA Technology MicroMap system was designed for the detection of corrosion, erosion or pitting at the inner surface of plant equipment. This system provides real time colour graphic images of corrosion or erosion (corrosion maps) by the use of:

- A standard 0° transducer with a Light Emitting Diode (LED) attached to it.
- A closed circuit video camera and the AEA video-tracking system to provide X-Y-coordinates of the hand-held or automated transducer.

During the scanning process the measured thickness is assigned to a particular colour that represents a thickness range. The specific location of the measurement is determined by the video tracking system. The colour value and the co-ordinates are then combined by MicroMap to produce a corrosion map (see Fig. 1) of the internal surface condition.

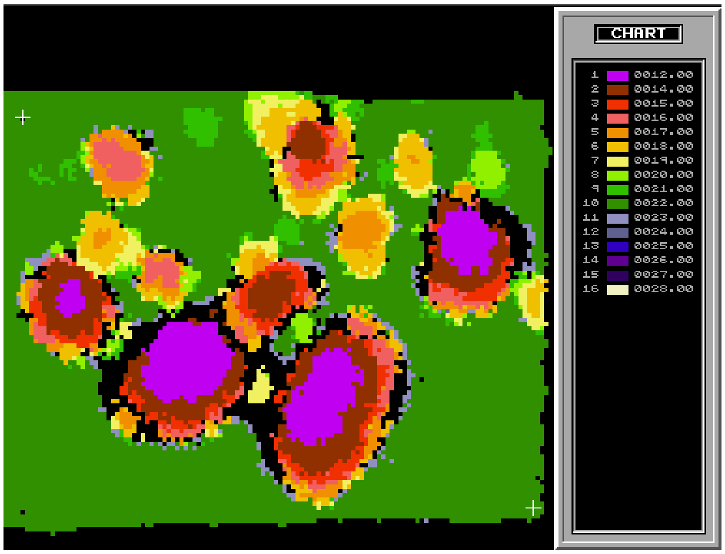

Fig. 1 Corrosion map generated by MicroMap

AEA Technology ESCOD System

A manual shear wave inspection approach can detect and size cracking at the scan surface. However the monitoring of the cracks becomes problematic, due to operator differences and no electronic image mapping technique, with hardcopy ability. This deficiency can be overcome by the use of AEA Technology's MicroMap system.

A shear wave probe, with the LED attached, replaces the 0° compression wave probe used for corrosion mapping. A 0°-10Mhz Kraut Kramer high resolution probe of 6mm in diameter with a 45° wedge would be a typical replacement probe. With this replacement, the area of interest would be between half and full skip. Fig. 2 presents a defect map generated by the MicroMap system using the ESCOD principle.

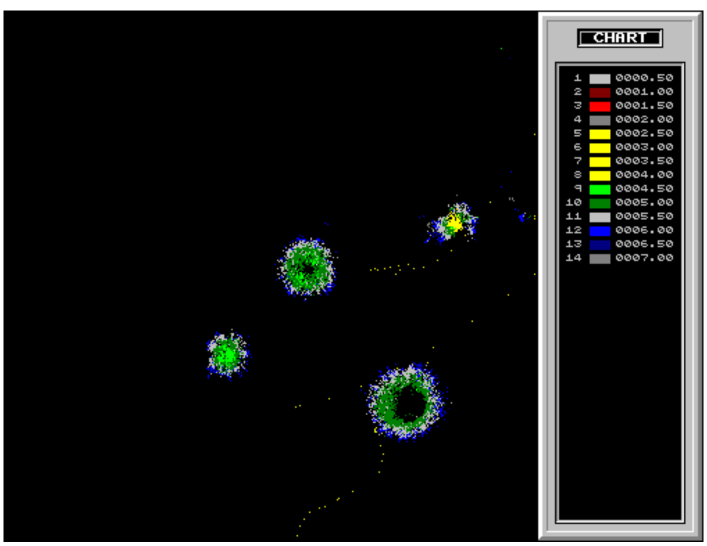

Fig. 2 Defect map generated by ESCOD

Modification of the MicroMap Setup

The compression probe allows for a thickness measure of throughwall loss to be noted, however with replacing the compression probe with a shear wave probe the measurement is altered from a throughwall thickness to a Beam Path Length (BPL) measurement. This measurement difference would make all readings received by the imaging system appear deeper than the actual thickness, therefor equivalent velocity and calibration delay values need to be determined.

The equivalent velocity (V_{eq}) is determined by applying the following equations:

$$Full\ skip\ BPL_s = 2t \cdot \tan(\theta) \qquad \text{Eq. 1}$$

$$V_{eq} = \frac{t \times V_s}{Full\ skip\ BPL_s} \qquad \text{Eq. 2}$$

where: Full skip BPL_s = Beam path length at full skip (mm)
t = material thickness (mm)
V_s = shear velocity (m/s)
θ = angle rating of wedge

Similarly, the equivalent calibration delay (D_{eq}) is determined by applying the following equations:

$$D_{eq} = \frac{t \times D_s}{Full\ skip\ BPL_s} \qquad \text{Eq. 3}$$

where: Full skip BPL_s = Beam path length at full skip (mm)
t = material thickness (mm)
D_s = shear delay obtained from shear wave probe calibration

By applying these equivalent calibration techniques it must be noted that the ESCOD system will not give readings from good material, therefore if colours are imaged, there are defects within the area of interest, which are between half and full skip of the shear wave probe.

EXPERIMENTAL VERIFICATION OF THE ESCOD SYSTEM

Test Plate Specifications

Two 304L test plates were manufactured for the verification of the Penetrant inspection method, and were used to determine the effectiveness of the ESCOD technique on the same type of defect. The specifications of the test plates are presented in Table 1.

Table 1. Test Plate Specifications

Test Plate 1		Test Plate 2	
Description	Specification	Description	Specification
304L Plate	5.5 mm thick	304L Plate	5.5 mm thick
Hole 1	ø 1 mm × 0.3 mm deep	Hole 1	ø 0.8 mm × 0.3 mm deep
Hole 2	ø 1 mm × 0.6 mm deep	Hole 2	ø 0.8 mm × 0.6 mm deep
Hole 3	ø 1 mm × 0.9 mm deep	Hole 3	ø 0.8 mm × 0.9 mm deep
Hole 4	ø 1.5 mm × 0.3 mm deep	Hole 4	ø 0.8 mm × through-wall
Hole 5	ø 1.5 mm × 0.6 mm deep	Hole 5	ø 1 mm × through-wall
Hole 6	ø 1.5 mm × 0.9 mm deep	Hole 6	ø 1.5 mm × through-wall
Hole 7	ø 1 mm × through-wall		
Hole 8	ø 1.5 mm × through-wall		

Fig. 3. Plate 1

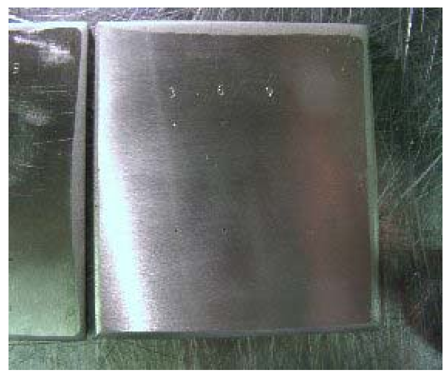

Fig. 4. Plate 2

Experimental Test Results

The experimental inspection results are presented in Table 2 and Table 3. The graphical test results, the SCC maps, are shown in Fig. 5 and Fig. 6.

Table 2. Inspection Results of Plate 1

Hole number	Minimum measured thickness (mm)	Estimated thickness reduction (mm)	Actual hole depths (mm)
Hole 1	5.0	0.5	0.3
Hole 2	4.8	0.7	0.6
Hole 3	4.4	1.1	0.9
Hole 4	1.7	3.8	Through-wall
Hole 5	1.62	3.88	Through-wall
Hole 6	5.1	0.4	0.3
Hole 7	4.7	0.8	0.6
Hole 8	4.3	1.2	0.9

Table 3. Inspection Results of Plate 2

Hole number	Minimum measured thickness (mm)	Estimated thickness reduction (mm)	Actual hole depths (mm)
Hole 1	5.2	0.3	0.3
Hole 2	4.75	0.75	0.6
Hole 3	4.3	1.2	0.9
Hole 4	1.8	3.7	Through-wall
Hole 5	1.62	3.88	Through-wall
Hole 6	1.73	3.77	Through-wall

The results presented in Table 2 and Table 3 clearly show that the depths of the indications are measured accurately. However, since the system calibration and gate settings were set to detect defects up to 4mm deep, the through-wall defects were not be sized accurately, but were noted as having a 4mm loss from 5.5mm

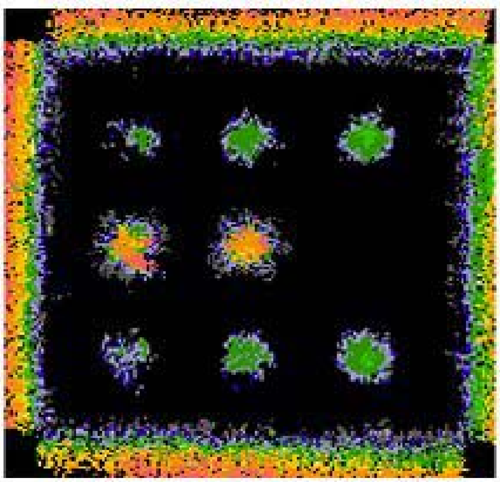

Fig. 5. Plate 1 Test Results

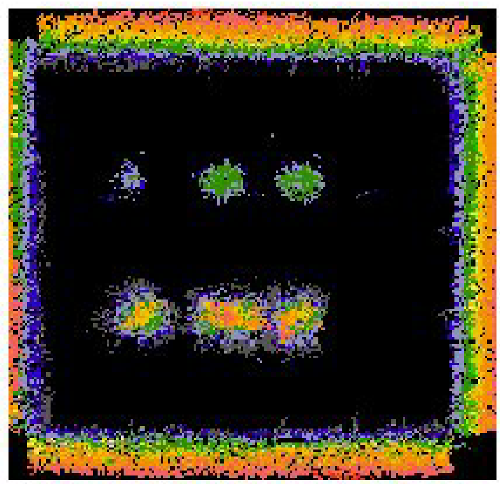

Fig. 6. Plate 2 Test Results

Capability of Detection

The MicroMap System offers the facility of changing the pixel size, i.e. the scanning resolution. For rapid scanning a large pixel size is usually selected and for high-resolution scans a small pixel size would be selected.

By testing the capability of detection of the ESCOD system it was found that, similar to corrosion mapping, the larger pixel size allows for quick scanning with a lower capability for detection of small defects. A small pixel size provides for a higher capability of detection with more definition while adding to the time required to complete the inspection.

Site Testing of ESCOD

The ESCOD inspection technique was applied to a 304L pipeline (see Fig. 7) with no known indications. The nominal wall thickness of the pipe was 3.5 mm.

The pipe length was divided into two bands, which were respectively divided into four separate quadrants for ease of camera usage.

Fig. 7. Site Inspection on 304L pipe

The results of the inspection noted indications at the outer surface of the pipe, this pipe was penetrant inspected and no indications were noted over the area inspected. The table below shows the results of the ESCOD inspection.

Table 4. Inspection Results of 304L pipe

Scan ID	Minimum measured thickness (mm)	Estimated thickness reduction (mm)	Actual defect depths (mm)
Pipe Band 1			
Scan A	1.6mm	1.9mm	To be Determined
Scan B	3mm	0.5mm	To be Determined
Scan D	1.76mm	1.74mm	To be Determined
Pipe Band 1			
Scan A	2.5mm	1mm	To be Determined
Scan B	2.7mm	0.8mm	To be Determined
Scan D	2.9mm	0.6mm	To be Determined

CONCLUSIONS

The ESCOD technique performs well in the detection, sizing and monitoring of indications that could previously not be quantified by the use of conventional techniques such as penetrant, magnetic particle and visual. However, the technique is limited by the surface condition, e.g. badly eroded surfaces etc.

The application of this technique also proves to be a cost effective inspection method when considering the cost of replacing sections of piping, vessels, etc. compared to monitoring of the indications linked to a life assessment and risk management program.